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NOTE ON THE SELF-ADJUSTING INTERFEROMETER IN RELATION TO THE ACHROMATIC FRINGES

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1. Introductory.—This apparatus was first used for the case of coincident ray systems by Michelson and Morley[1] in their famous experiments on the Fresnel-Fizeau coefficient and has since been similarly employed by Zeeman.[2] It has so many practical advantages that a special reference here is justified. It is shown in a modified form[3] in figure 1, where L is a pencil of white light preferably from a collimator. It is separated by the half silvered plate N into the two beams $L12345T$ and $L16785T$, both of which are recombined at 5 and then enter the telescope at T. It is merely necessary to rotate any of the mirrors, say N, around a vertical axis until the two vertical white wide slit images coincide in the telescope, when brilliant fringes will be at once obtained on the coincident white fields. The central fringe is achromatic, for the system is self-compensating, or the glass paths are rigorously equal. The fringes may be enlarged to infinite size and then reduced in size again, the phenomenon being symmetrical, by rotating any mirror, say N, about a horizontal axis.

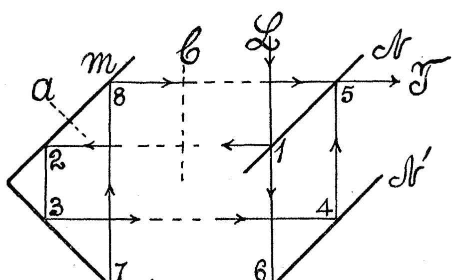
The mirrors N and N' are rigidly fixed to a carriage capable of sliding right and left parallel to the lines 85, etc. Hence the rays 85 and 21 and the rays 34 and 76 may be brought to coincidence or separated in any degree, at pleasure. If the slide were perfect the fringes would not be disturbed by this process; but few slides are perfect to this degree, and the fringes will change size somewhat, since there is rotation. Practically this is of no consequence.

The fringes, which when sharp are necessarily horizontal, may also be changed in size by inserting a plate glass compensator about 5 mm. thick in the paired beams 85, 21, or 34, 76. When this is rotated on a horizontal axis, the fringes pass through infinite size, and this arrangement is particularly adapted for the detection of the character of the fringes and will be so used presently.

If a direct vision prism or grating is placed in front of the telescope, the spectrum is seen to be crossed by intense black lines, very nearly parallel and horizontal, but actually diverging from blue to red symmetrically up and down from the horizontal central black line. It is not necessary here, that the slit be fine. In fact it may be several millimeters broad without destroying these spectrum fringes, if essentially horizontal.

If the linear phenomenon of reversed spectra, coinciding on a certain line of the spectrum is wanted, a prism may be inserted between m and m' suitably adjusted. These fringes then also appear at once and may be put in any color, at pleasure, on rotating any mirror, say N, on a vertical axis. Rotation on a horizontal axis enlarges.

Finally if separate plate glass compensators are placed in the paired beams 85 and 21, for instance, and rotated around a horizontal axis independently, the fringes may be displaced up or down the slit image for the purpose of measurement. A double offset air compensator consisting of 3 right-angled



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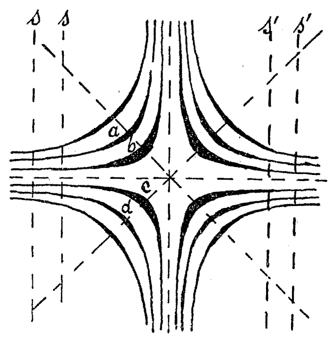

2

V-mirrors with their corresponding faces parallel, the central V-mirror movable on a micrometer (described in my paper on gravitation) is particularly available. Such a compensator would be placed normally to the rays 85 and 21, for instance, to give them lateral path length. In these cases the spectro-telescope may also be used, where the strong bands register the displacement in any wave length. Since the slit may be broad, there is here also a great abundance of light.

The rays 85, 21, may be made of almost any reasonable length, and distance apart, if the mirrors N, N', m, m', are broad. To secure greater length, the mirrors mm' (rigidly connected) may be moved at pleasure in the direction 58, without disturbing the fringes, good slides presupposed. The rays 85 and 21, 34 and 76 may be separated, if x is the available breadth of mirror to an extent x cos 45°, by moving the rigid system NN' in the direction 85.

If either of the mirrors m or m' is separated (as for instance at a in figure 6), the part may be placed on a micrometer; but the apparatus would not then be selfadjusting; for the parts will not in general be coplanar.

To secure the best conditions for sharp strong fringes the two slit images seen in the telescope must be of equal intensity, and this depends on the half-silver N. On testing a number of plates it is usually easy to find one which fulfills this condition nearly enough. The fringes are still good, even when the intensity of images is noticeably different. The secondary images due to the reflection from glass faces are either weak or (if thick plates are used) these reflections may be blotted out by small opaque screens suitably fixed to the mirrors m and N. It is interesting to observe that with proper adjustment these secondary reflections carry their own fringes, some of which are modified in like conditions more rapidly than the main set. Intersecting fringes producing a beaded structure and fringes moving in opposite directions are also observed.

2. *Character of the achromatic fringes.*—Since the achromatic fringes are quite symmetric, consisting of a central white or fringe, flanked on either side by 3 or 4 colored fringes rapidly decreasing in intensity, it is obvious that (practically) they must consist of superposed monochromatic confocal hyperbolae. This may be well shown in the present apparatus, where the fringes are stationary and are displayed relative to horizontal and vertical lines of symmetry. To carry out the experiment, it is best to insert a single plate compensator (say C, fig. 6, 5 mm. thick) normally into the rays 85 and 21, preferably in the same vertical plane. When the plate is not perfect, it may be necessary to adjust for coincidence of slit images. If now this plate is rotated about a horizontal axis (normal to the lines 85, 21) the fringes walk laterally through the broad coincident slit images, in such a way as to clearly outline a moving design of the form given in figure 2. In other words, as a first approximation (for the case is, of course, essentially more complicated) the achromatic fringes may be assumed to be a family of confocal equilateral hyperbolas, referred to given horizontal and vertical axes. When the rays 85, 12 are at the same level, the broad slit image is in a position of symmetry relating to the hyperbolae, figure 2. When this is not the case, the image is at ss or $s's'$, with the fringes very rapidly becoming horizontal. Since this design is similarly carried out with decreasing coarseness from red to violet, it is clear that a single characteristic central achromatic fringe results, invaluable for purposes of displacement interferometry, from its smallness and since from the breadth of slit it can be made so intensely luminous. When the path difference of the rays 85, 12, in figure 1 is changed by the micrometer or by independent compensators, the figure 2 shifts bodily up or down the slit image. It is also obvious that when the fringes with white light are horizontal, they must appear as horizontal black bands in the spectro-telescope, regardless of the width of slit used; and hence these fringes also are excessively luminous, while their displacement may be referred to a definite wave length. If the interferometer is not selfadjusting, the axes of figure 2 are as a rule inclined, and fringes are obtained in all angles of altitude needing special adjustment. The spectrum fringes then demand a fine slit but are also hori-

zontal. The shift of achromatic fringes due to micrometer displacement may therefore be at once expressed in terms of the spectrum fringes rigorously in a given wave length.

A very interesting transformation of the design, figure 2, will be noticed, if by rotating any of the mirrors, N, m, figure 1 for instance, the two white slit images seen in the telescope, are passed horizontally through each other. During this motion the originally vertical, nearly linear achromatic fringe, passes through the form of the area between the hyperbolae a and b, figure 2; next through the area between b and c (coincidence of slit images); then into the area between c and d; finally again into a vertical hair line, always retaining its individuality among the surrounding colored fringes of similar shapes. The whole is particularly vivid if the fringes are observed with the ocular drawn well forward, quite out of focus. The same may be done by adding a diopter spectacle lens (convex or concave), to the objective. The bearing of this will be seen presently.

3. *Curved compensators.*—If the rays 85, 21 in figure 1 are brought to coincidence, it is obvious that a lens, either convex or concave, may be inserted between the mirrors m and m' and normal to the rays, without destroying the interferences, though they must be greatly modified in form. If the lens is symmetrically inserted, the two broad slit images will be equally wide, so that coincidence is perfect. The fringes so obtained are usually large, brilliantly colored circles. In case of imperfect plate they become oval and coarse. The large central disc is achromatic. To center the fringes the mirror m' may be rotated on a vertical and horizontal axis, until the symmetrical circular figure is obtained. Here again the individuality and even the approximate position of the achromatic fringe is retained on passing the broad slit images through each other; but the sequences of types of fringe is peculiar. As the slit images separate toward the right or the left, because of the corresponding rotation of m on a vertical axis, the originally colorless disc of the circular fringes not only moves to the right or left, but at the same time becomes very vividly colored. The coarse fringes now show considerable resemblance to the coronas of cloudy condensation, in which there is also a colored disc. When the slit images have been markedly separated, the disc vanishes and thinner lines appear, at first as complete circles surrounding the fading disc, but rapidly losing curvature to become vertical. Throughout the whole transformation there has been a grouping of symmetrically concentric colored circles, on both sides of the achromatic circle. To state this differently: each originally linear fringe, in turn, on expanding (slit images approaching coincidence), contracts vertically and broadens horizontally into a disc, which retains the color of the fringe out of which it originates. The same result may be obtained by moving the lens inserted between m and m' into both rays, fore and aft (direction 8, 5). Similarly the corresponding sequence between horizontal fringes appears, on moving the lens up and down. If the m, m', mirrors are moved bodily fore and aft, however, the circular

fringes merely pass horizontally through the field without appreciably changing form.

It makes little difference whether concave or convex lenses are inserted between m and m', except that the objective of the telescope will have to be armed with a convex or a concave lens (of the same strength) respectively, to assist in focussing. But here again the most vivid effects are obtained with the ocular drawn out of focus. I examined lenses of 1, 2, and 3 diopters of focal power, concave and convex. There would be nothing against the treatment of stronger lenses, only the secondary adjustments become increasingly difficult, unless special devices are resorted to. Many of the forms are quite visible to the naked eye.

If the lens is not symmetrical in form, i.e., for plano-convex meniscus and other lenses, the simple figures above discussed become more complicated fand the fringes multi-annular.

4. *Index of refraction, irrespective of form.*—If a plane-parallel trough containing a solution of mercury potassic iodide is placed between m and m', figure 1, normally to the rays, neither the achromatics nor the spectrum fringes (broad slit admissible) are affected. Inclination to the normal position will change the size of fringes only. Hence if a piece of glass is inserted into the trough with the rays separated as at 2, 3 and 8, 7 in figure 1, one of them (say 8, 7) only passing through the glass, the spectrum fringes will change form or vanish except at that part of the spectrum in which the index of refraction of the glass and of the solution are identical supposing the dispersion coefficients to be nearly enough the same. It is thus of interest to determine to what degree this method can be practically utilized.

In the case of bodies of regular form, like lenses, spectrum fringes and even achromatics will usually appear, when the sharply seen, fine slit images coincide in the principal focus (i.e., the position of the ocular for parallel rays). But the fringes will as a rule be in other focal planes.

5. *The same. Glass plate.*—In relation to the principle, §4, in question, if a plate of glass of higher refractive index is introduced into the solution and traversed by one ray only, the original intensely black, nearly horizontal bands in the spectrum are changed to much finer lines, at a considerable angle (45°, etc.) to the horizontal. This inclination is symmetrically down toward the red, or up toward the red, according as one beam or the other traverses the glass. Moreover the size of the fringes now decreases, in much more pronounced ratio from red to violet. The achromatics have necessarily vanished. It would need special compensation (horizontal spectrum fringes) to restore them and from this compensation the difference of index between solution and glass could be computed. Had there been no difference, the horizontal fringes would have been retained in that part of the spectrum. Such experiments may be made with astonishing ease and accuracy, and I hope soon to communicate quantitative results bearing on this and the preceding paragraph.

[1] *Amer. J. Sci., New Haven*, **31**, 1886, (377).

[2] *Proc. Amsterdam Acad.*, **17**, 1914, (445); and **18**, 1915, (1).

[3] This modification is essential, as the symmetrical apparatus of Michelson aud Morley does not admit of ray separation.

A COMPARISON OF WHITE AND COLORED TROOPS IN RESPECT TO INCIDENCE OF DISEASE

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This paper is an analysis of over half a million admissions to sick report of troops in camps in the United States. Of these 531,445 were for whites and 15,186 for colored troops. The relative frequency of disease in the two 'races' was as 974 to 1155; that is, the colored troops were about 19% more liable to go on sick report than the white troops.

The grounds of sick report are very numerous; so we shall consider only the commoner ones. All comparisons will be of the so-called mean annual rate per 1000 men. The data are those collected for the Report of the Surgeon General of the Army, 1918. Some comparative data have occasionally been included derived from the nine preceding annual reports.

In many cases the morbidity rate is almost the same for the white and colored troops. In this paper particular attention is paid to those diseases that have a strikingly different rate in the two races. It is to be kept in mind that all troops had been subjected to the same examination at induction, in order to exclude chronic diseases; and that they lived under equally good sanitary conditions.

First, may be considered the diseases that are commoner in colored than in white troops. These fall into four groups (a), those in which the excess is due to the fact that fewer of the colored men had become artificially immunized by inoculation before, or at, mobilization. They probably brought their disease to camp; or failed to get a reaction there; (b) those in which there is a lower natural immunity in the negro; (c) venereal disease and its complications, (d) other diseases.

(a) Of the diseases that are due to lack of acquired immunity, smallpox is the most striking. The morbidity rate for this disease is for colored troops 9 times that for white troops (there being 146 admissions altogether). Chickenpox was relatively 8 times as common in colored as in white troops.

(b) Of the diseases for which negroes lack relative natural resistance tuberculosis of the lungs and pneumonia take first places. There were over $2\frac{1}{2}$ times the admission rate for tuberculosis of the lungs in colored as in white troops in 1917. This is a little greater difference than the average of the past